DAO, HARMAKHIS, AND REULL VALLES: THE ROLE OF OUTFLOW CHANNELS IN THE DEGRADATION OF THE CIRCUM-HELLAS HIGHLANDS OF MARS. ***David A. Crown and Scott C. Mest,*** *Department of Geology and Planetary Science, University of Pittsburgh, Pittsburgh, PA 15260*

Geologic deposits and landforms representative of much of the planet's history are preserved in the southern cratered highlands of Mars. The circum-Hellas highlands to the east of the basin record the effects of volcanism, tectonism, fluvial erosion and deposition, aeolian activity, and mass-wasting. Mapping studies and geomorphic analyses have provided a general understanding of the evolution of the Hellas region [1-3], placed constraints on the styles and timing of volcanic activity associated with Hadriaca and Tyrrhena Paterae [3-7], and investigated Dao and Harmakhis Valles and the terminus of Reull Vallis [3,8,9]. The spatial and temporal association between source regions for Dao and Harmakhis Valles and volcanic materials associated with the paterae suggest that volcano-ice interactions may have contributed to and possibly triggered outflow channel formation [3,10]. Recently, geologic mapping studies in the eastern Hellas region (27.5-42.5°S, 245-270°W) have been extended from the Hadriaca/Tyrrhena Paterae region into the highlands of Promethei Terra [11,12] in order to examine the entire Reull Vallis outflow system and to analyze highland evolution outward from the Hellas basin. The present study provides a detailed comparison of Dao, Harmakhis, and Reull Valles and examines the role of highland outflow channels in the degradation of the region.

Dao Vallis

Dao Vallis extends for ~1200 km from the eastern margin of Hadriaca Patera; its orientation changes from NE-SW to E-W just upstream from an escarpment at the margin of Hellas Planitia, from which it continues onto the floor of the basin. Dao Vallis consists of two parallel canyons which join at the southeastern margin of the volcano; the apparent flow direction (NE to SW) is consistent with regional topography. Two steep-walled, closed depressions are the apparent source regions; they have smooth floors with some small knobs, which may be remnants of collapsed plains or accumulations of sedimentary debris. The main channel system of Dao Vallis (6-50 km wide) exhibits the following forms: 1) a steep-walled, scarp-bounded depression, 2) irregular depressions resulting from collapse and fracturing of the surrounding plains; in these regions, Dao Vallis is shallower and its floor contains numerous hills and knobs, 3) a series of parallel runoff channels in a trough eroded into the plains, and 4) slumped or subsided regions that retain the characteristics and structures of the surrounding plains. Where Dao Vallis is steep-walled, its floor is typically smooth and may contain either a few knobs or apparent flow lineations parallel to channel walls (more common downstream) [3].

Dao Vallis cuts units of volcanic and probable sedimentary origin of Hesperian and possibly Amazonian age [3]; no layering is observed in channel walls. Small runoff channels are found adjacent to Dao Vallis in the channeled plains rim unit [1,3]; most of these are parallel to the canyon system, and others have N-S orientations. Dao Vallis truncates small fluvial channels on the flanks of Hadriaca Patera and in the surrounding plains. The collapse depressions at its source are connected to the main channel system by a region of subsided plains; this indicates that subsurface flow was involved in the formation of Dao Vallis. At its terminus, a small channel cuts an apparent depositional lobe extending from a larger canyon at the margin of Hellas Planitia.

Harmakhis Vallis

Harmakhis Vallis is a single, ~800 km-long canyon, parallel and to the south of Dao Vallis, and extends to the SW from a region of resurfaced cratered highlands; its orientation changes to E-W prior to crossing the escarpment at the edge of Hellas Planitia. The source of Harmakhis Vallis is a 40 x 80 km, scarp-bounded depression with a smooth floor containing small hills; much of the floor is covered by younger debris aprons shed from adjacent highlands. The main channel (8-60 km wide) cuts the Amazonian/Hesperian channeled plains rim unit [3] and is slightly more sinuous than Dao Vallis. Harmakhis Vallis consists of regions with irregular walls defined by collapse and fracturing of the plains, some of which are preserved as slumped, fractured remnants adjacent to the source depression. The remainder is a steep-walled, smooth-floored depression with some flow lineations parallel to its walls; no layering is readily apparent. As with Dao Vallis, small channels adjacent and parallel to the main canyon are observed, as well as others with N-S orientations [8,9]. To the SW, Harmakhis Vallis appears to have been infilled by wall collapse; its walls are less regular and scarps are evident in the channeled plains rim unit, which has a hummocky appearance next to Harmakhis Vallis. On the floor of the Hellas basin, Harmakhis Vallis is a subdued network of small channels; no clear evidence of deposition is observed.

Reull Vallis

Reull Vallis is an extensive (~1500 km long) and morphologically diverse channel system. It consists of three main segments and extends from the ridged plains of Hesperia Planum (N-S orientation) through resurfaced highlands in Promethei Terra (NE-SW orientation) and finally through the channeled plains rim unit (SE-NW orientation) where it may have intersected the source depression of Harmakhis Vallis. In this area, Reull Vallis is obscured by a debris apron; many prominent debris aprons are evident along Reull Vallis in the highlands [3,11-13]. The source area consists of several small channels that converge in a large irregular depression in the ridged plains. Reull Vallis is a single canyon (5-50 km wide) with a tributary side canyon at the junction of the final two segments. Its degree of sinuousity varies significantly along its length. The channel system is not continuously defined; near the junction of segments 1 and 2, it is apparently covered by young sedimentary plains [11].

Segment 1 of Reull Vallis, which includes its source region, is typically smooth-floored but shows evidence of erosion by surface runoff, has irregular walls exhibiting some small-scale layering, and contains streamlined features and inliers of the ridged plains. Segment 2 consists of an upper part that has a high sinuousity, exhibits local layering along its walls, and contains flow lineations on its floor; its lower

part has a smooth floor and flow lineations and has been enlarged by wall collapse. These are separated by an elongated basin which has been infilled by material with a pitted surface that may be continuous with the surrounding plains. In segment 3, prominent and laterally continuous layers can be observed within Reull Vallis and the large tributary canyon to the SW [3]. Here, Reull Vallis is a wide canyon with irregular walls and smooth-surfaced floor materials displaying some lineations. Adjacent to segment 3, the surrounding plains show erosional scarps, mesas, and small runoff channels aligned with canyon walls [3]. Mesas to the south of Reull Vallis in this area and plains adjacent to segment 2 may be exposures of smooth plains emplaced early in the development of Reull Vallis [11]; erosion of these units is most extreme along segment 3. The Reull Vallis system cuts through units of Amazonian, Hesperian, and Noachian age, but in most cases is contained within large-scale volcanic units and probable sedimentary plains that have resurfaced low-lying regions in the cratered highlands. Embayment and cross-cutting relationships suggest that the fluids that moved through Reull Vallis may have been responsible for the emplacement and later erosion of some of the sedimentary units.

Role of Outflow Channels in Highland Degradation

Analysis and comparison of cross-cutting relationships between outflow channels and adjacent plains, and of the morphologic characteristics of channel source regions, walls, and floors, illustrate the processes involved in the development of the eastern Hellas outflow channels and their role in the evolution of the Martian highlands. Dao and Harmakhis Valles have previously been interpreted to be collapsed regions of volcanic and sedimentary plains that were eroded by a combination of surface and subsurface flow [3,10,14]. Reull Vallis has a similar but more varied morphology. No distinct remnants of slumped or subsided plains units are contained within its canyons, although in several regions the channel system takes a form similar to collapse depressions found in the source regions and within the main channels of Dao and Harmakhis Valles. Both Dao and Harmakhis Valles exhibit evidence of subsurface flow, with the most obvious adjacent to Dao Vallis' source regions. The lack of preserved evidence for collapse and subsurface flow along Reull Vallis suggests that this may be a more mature and long-lived system. Aside from the junction of segments 1 and 2 that appears to have been covered by a plains unit, Reull Vallis is a continuously-defined channel along its entire length. The recent identification of a series of probable sedimentary plains adjacent to segment 2 of Reull Vallis [11] and the apparent continuity of one of these units with materials on the floor of a basin along this segment indicate that Reull Vallis has had a complex, multi-staged history and that fluids moving through the channel system may have had a significant role in both the resurfacing of low-lying regions of the highlands and erosion of plains units adjacent to the channel. The morphologic changes observed along Reull Vallis, including evidence for small-scale layering along its floor and walls and exposure of laterally continuous layers in segment 3, are consistent with this scenario. No evidence of exposed stratigraphy is apparent in the walls of Dao and Harmakhis Valles, and deposition associated with these systems appears to be confined to their floors and to the floor of the Hellas basin. Although Reull Vallis directly truncates Noachian highland units in a few places, all of the channel systems primarily cut Hesperian and possibly Amazonian plains. The proximity of all outflow channel source regions to units interpreted to be volcanic in origin suggests that channel formation may have been precipitated by volcanic activity. Similarities in the surface characteristics of debris aprons and plains units adjacent to and associated with Reull and Harmakhis Valles suggest a late-stage regional style of degradation. Age determinations constrained by crater densities should result in more detailed documentation of highland evolution and an understanding of the volatile history of the region.

References: [1] Greeley, R. and J.E. Guest, *U.S. Geol. Surv. Misc. Inv. Ser. Map, I-1802B*, 1987. [2] Tanaka, K.L. and G.J. Leonard, *J. Geophys. Res., 100*, 5407-5432, 1995. [3] Crown, D.A., et al., *Icarus, 100*, 1-25, 1992. [4] Greeley, R. and D.A. Crown, *J. Geophys. Res., 95*, 7133-7149, 1990. [5] Crown, D.A. and R. Greeley, *J. Geophys. Res., 98*, 3431-3451, 1993. [6] Crown, D.A. and R. Greeley, Geologic map of MTM quadrangles -30262 and -30267, Hadriaca Patera region of Mars, U.S.G.S., in review, 1997. [7] Gregg, T.K.P., et al., *U.S. Geol. Surv. Misc. Inv. Ser. Map I-2556*,in press, 1997. [8] Price, K.H., *Lunar Planet. Sci. Conf., XXIV*, 1179, 1993. [9] Price, K.H., Geologic map of MTM quadrangles -40262, -40267, and -40272: Dao, Harmakhis and Reull Valles region of Mars, U.S.G.S., in review, 1997. [10] Squyres, S.W., et al., *Icarus, 70*, 385-408, 1987. [11] Mest, S.C. and D.A. Crown, 1997, this issue. [12] Mest, S.C. and D.A. Crown, 1996, *Geol. Soc. Am. Abstracts with Programs*, A-128. [13] Stewart, K.H. and D.A. Crown, this volume. [14] Baker, V.R., *The Channels of Mars*, 1982.